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Redesigning a Freshman Engineering Course to Promote Active Learning by Flipping the Classroom through the Reuse of MOOCs

CARLOS ALARIO-HOYOS, IRIA ESTÉVEZ-AYRES, CARLOS DELGADO KLOOS, PEDRO J. MUÑOZ-MERINO, ENRIQUE LLORENTE-PÉREZ, JULIO VILLENA-ROMÁN

Telematics Engineering Department, Universidad Carlos III de Madrid, Avda. Universidad, 30, 29811, Leganés, Madrid, Spain. Email: calario@it.uc3m.es, ayres@it.uc3m.es, cdk@it.uc3m.es, pedmume@it.uc3m.es, 100315051@alumnos@uc3m.es, jvillena@it.uc3m.es

Abstract

MOOCs have made it possible not only to provide quality open education for any learner worldwide, but also to rethink the way on-campus teaching is delivered. The materials produced for a MOOC can be consumed by on-campus students before arriving to the classroom, using class time to activities that promote active learning, following this way a flipped classroom strategy. This paper presents the experience of redesigning a first-year engineering course with a large number of students (over 400 each year), in which MOOCs are reused, and a flipped classroom strategy is implemented, dedicating most of traditional lecture time to do hands-on, interactive activities. The results show an increase in students' motivation, both in the use of MOOC content outside the classroom, and in the realization of hands-on, interactive activities inside the classroom. In relation to the teacher, having information on students' previous work outside the classroom, and on students' work in the hands-on, interactive activities carried out inside the classroom, allows understanding better the differences between groups, tailoring the explanations during class time, and providing proper reinforcement activities to be done after class.

Keywords: Flipped classroom; MOOCs; active learning; engineering education.

1. INTRODUCTION

MOOCs (Massive Open Online Courses) have become a marketing tool for universities, as they allow reaching learners all over the world, and promote the university brand through quality courses [1]. However, the development of MOOCs entails a high cost, not only in equipment and other production resources, but also in personnel time, both for teachers and supporting staff (e.g., technicians, audiovisual staff, instructional designers, etc.) [2]. For this reason, universities are now reflecting on the life cycle of the MOOCs they produce, exploring ways to reuse the quality educational content generated for this type of courses (content which is reviewed by thousands of learners, and usually improved by the teachers in subsequent editions of the MOOC) to be offered also to residential students, integrated in on-campus traditional programs [3].

The reuse of MOOCs in on-campus programs can be articulated at various levels of coupling with respect to curricula [3]. In *loosely-coupled* scenarios, MOOCs can be offered as supplementary content, either for students to revise concepts explained in class and prepare themselves for exams, or to delve into cross-curricular topics which are not addressed during the course due to time constraints and/or syllabus restrictions. In *tightly-coupled* scenarios, MOOCs can be integrated with classroom sessions allowing a redesign of each individual class and the implementation of flipped classroom strategies, where learners spend time at home understanding the theoretical concepts (through contents available in the MOOC), and subsequently dedicate classroom time to activities which foster active learning, such as problem solving or small group projects [4].

However, implementing a flipped classroom strategy by reusing MOOCs involves a double change of mind. On the one hand, students must get used to working at home, before the class, in order to acquire the minimum background needed, or their time in the classroom will be unproductive [5]. This problem is aggravated in the case of freshmen, who typically have a lower culture of constancy and work outside the classroom, and who still need to develop self-regulated learning skills, such as the definition of comprehensible learning objectives or the proper management of working time. Strategies that focus on strengthening students' motivation can contribute precisely to this change of mind, including the presence of gamified elements which encourage students to work beyond class time and that increase their awareness on the importance of doing prior work before going to the classroom [6]. On the other hand, teachers must design activities for the classroom which add value to the content already offered through the MOOC, or they will face the risk of low student attendance. Redesigning all classes anew, so that these include practical activities aimed at fostering a more active learning [7], demands an important workload. Furthermore, these practical activities must have an appropriate level and depth (taking into account the previous work students have actually done at home), which becomes particularly challenging in courses with a large number of students, as the backgrounds these develop at home might be very heterogeneous [8].

Therefore, the implementation of a flipped classroom strategy through a tightly-coupled reuse of MOOCs is especially complex in the case of first-year undergraduate courses, since students usually lack self-regulation skills, and the teacher must design classroom activities for a large number of students with heterogeneous backgrounds. This raises the research questions of: (1) how to redesign freshman courses which meet the aforementioned constraints? and (2) how to empower students to bring about the necessary change of mind on their side by increasing their motivation towards the flipped classroom instructional model?

This paper presents the results of an experience which consists of a tightly-coupled reuse of MOOCs in a first-year engineering course for implementing a flipped classroom strategy, and where face-to-face sessions are redesigned to include hands-on, interactive activities aimed at fostering active learning. This first-year course is "Systems Programming", the second course on programming that students from four bachelor's degrees related to Telecommunication Engineering take at Universidad Carlos III de Madrid (UC3M), Spain. Systems Programming normally has more than 400 enrollees average every year and can be taken either in English or Spanish. The MOOCs that were reused in Systems Programming belong to the edX professional certificate on "Introduction to Java Programming" (also by UC3M), and fully cover the syllabus of Systems Programming (besides other topics) [9][10]. With the aim to promote students' motivation towards the course and the flipped classroom strategy *outside the classroom*, a mobile gamified application called Flip-App [11], which compares the percentage of work done at home with that of classmates, is used. Moreover, with the aim to promote students' motivation towards the course and the flipped classroom strategy *inside the classroom*, a web-based interactive response system called Kahoot! [12], which ranks students according to their knowledge through a set of questions, is used.

The remainder of this paper continues with an analysis of the literature related to the implementation of active learning strategies and, particularly, flipped classroom strategies in the context of engineering education. Section 3 presents the redesign of the engineering course in which the flipped classroom strategy was implemented, detailing the work students do outside and inside the classroom. Section 4 presents and discusses the results, which are based on data collected from the aforementioned freshman engineering course. Finally, section 5 sets out the conclusions and identifies several future lines of work.

2. Flipping the Classroom in Engineering Education

One of the main concerns of today's teachers regarding the learning process is how to promote meaningful learning, i.e., that students instead of focusing on memorizing concepts, actually learn to do something with the acquired knowledge [13]. This problem is especially relevant in engineering education, given the strong practical component of study programs in this area [14]. Engineers are hired to solve problems, and their learning experiences, in order to be effective, must include, in addition to the acquisition of conceptual knowledge, the application of this knowledge to address complex problems of engineering practices [15]; in this way, effective learning experiences in engineering education shall address not only *surface learning*, but also *deep learning* [16].

There are different factors that influence students in their achievement of deep learning in a course [17]. The first factor is the *learning environment*, which includes the teaching style, the scope for discovery and problem-solving activities, as well as the opportunities for social interactions and collaborative learning. The second factor is the *course content*, which includes the concepts and themes to be addressed in the course, and how relevant these are to the student's career. The third factor refers to *individual characteristics of the learner*, such as prior knowledge, personality, metacognitive skills, or available work time. These three factors have a strong relationship with a fourth factor, student's *motivation and engagement with the course* [17]. If the student has low motivation, only surface learning is likely to be achieved, whereas if the student has high motivation, deep learning is more likely to be achieved. Teachers do not have much influence in the course content (as it is fixed in the syllabus approved by academic authorities), nor in the individual characteristics of the learner. Nevertheless, teachers decide how to design and implement the learning environment, which should aim to increase students' motivation, and, therefore, to foster the achievement of a deeper learning.

Although engineering education should be seeking the achievement of deep learning, the review by Baeten et al. [18] detected that, according to the studies which compared the achievement of deep learning in different disciplines, students in social sciences (including arts, politics, or philosophy) typically achieve a deeper learning compared to students in sciences (including economics, mathematics and engineering). Designing and implementing student-centered learning environments for engineering education can contribute to achieve a deeper learning (compared to teacher-centered environments). However, the literature also shows that student-centered learning environments do not always imply a deeper learning. [18]. For example, an innovative, student-centered assessment system can be a factor that discourages deep learning [19] (a surface learning might be enough to pass a course if the assessment system is not properly calibrated). On the contrary, if teachers are strongly involved and orient their practices seeking a change in students' minds, then students are more likely to achieve a deeper learning [20].

Learner-centered learning environments, unlike teacher-centered learning environments, empower learners to take responsibility for their own learning [21], moving from passive instruction to active learning strategies [21]. There are different strategies aimed at promoting active learning (e.g., problem-based learning, project-based learning, collaborative learning, flipped classroom, etc.), but they all share the same core element: the introduction of hands-on, interactive activities into traditional lectures. These activities shall be designed with the ultimate goal of increasing students' motivation and engagement [22], this being the key factor to achieve a deeper learning [17].

Research studies which compare traditional lectures with classes designed to make use of active learning strategies agree that they can be equivalent regarding the mastery of content. Nevertheless, active learning strategies excel, for example, when the aim is to promote the development of students' skills in thinking and writing [23]. Moreover, even when the aim is just to remember content, active learning strategies which introduce brief activities in the middle of lectures are better at helping students to remember more content [22]. Moreover, the use of active learning strategies in the classroom, especially if implemented through collaborative learning activities, is usually a way of improving student engagement with the course [24].

The flipped classroom is a relatively new active learning strategy which tries to change where the meaningful learning takes place [25]. Instead of devoting time in the classroom for explaining the most important concepts through lecturing, students work on these concepts outside the classroom reading documents or watching videos provided by the teaching staff. This approach leaves room to do practical activities inside the classroom, taking advantage of students' interaction with the teacher and other classmates [26]. Thus, with more time gained for teaching and learning in the classroom, instead of worrying about covering the whole course syllabus during class time (which is supposed to be prepared beforehand by the students), there is space for deepening in the key concepts though practice [27].

Although the concept behind the flipped classroom is not new, it comes at a time where technology has evolved in a way that quality audiovisual educational content can be provided at a low price, and where MOOCs have allowed teachers to rethink how they should explain the key concepts of their courses through short videos intertwined with formative activities and interactive resources [28]. In addition, Higher Education institutions are now receiving a new generation of students, called Millennials, who have coexisted with technology since childhood, and who regularly use technology in primary and secondary education classrooms. It is noteworthy that this new generation of students are used to a 24/7 connectivity and other ways to acquire information, relying more on audiovisual content and less on reading thoroughly through text documents. Even more important, this generation needs constant stimulation to thrive [29]. It is therefore necessary to offer learning environments that stimulate these new learners, increasing their motivation and engagement, achieving at the same time deep learning. Flipped classroom strategies have already shown successful in capturing Millennials' attention [7][30].

In the field of engineering education, flipped classroom has received less attention, and there is currently limited research on this area [31], especially in first-year undergraduate courses. Existing literature, however, reports positive effects in conceptual understanding, problem-solving skills, student retention and engagement [31][32]. Among the advantages reported in engineering education, authors in [33] and [34] report a high level of students' satisfaction with the flipped classroom. Authors in [35] report a flipped classroom experiment in a course with a large number of students, where these were pleased for being able to receive more feedback from the teacher and peers (compared to the traditional approach). Authors in [36] and [37] showed an improvement in students' performance for an experimental group which had a flipped classroom strategy implemented, in comparison to a control group which followed a traditional approach; an equivalent improvement was obtained by authors in [38], but comparing students' performance in a flipped classroom with that of previous years' students who followed a traditional approach. Moreover, authors in [39] reported an improvement in students' grades when using MOOC technology in the Khan Academy platform to implement a flipped classroom. However, some problems have been detected in the implementation of the flipped classroom for engineering courses. The additional students' workload required for implementing a flipped classroom strategy can make some students reluctant to accept it. This was the case reported in [40], where students preferred a mixture of classes which follow a flipped classroom strategy, and classes which follow a traditional lecturing style, to balance their workload over the weeks of the course.

In this context, it is necessary to develop more research on the implementation of flipped classroom strategies in engineering education courses, especially in what concerns to the integration of activities outside and inside the classroom, with the aim of distilling good practices and guidelines which can be extended to other educational contexts [31]. In particularly, this work focuses on how to reuse the contents developed for MOOCs as part of the activities that take place outside the classroom, and how to increase students' motivation and engagement, both outside and inside the classroom; and all this for a freshman engineering course with a large number of enrollees.

3. FLIPPING THE CLASSROOM IN SYSTEMS PROGRAMMING

Systems Programming is a first-year, second-semester programming course, taught in four bachelor's degrees in Engineering (Telecommunication Technologies Engineering, Communication Systems Engineering, Telematics Engineering, and Audiovisual Systems Engineering) at UC3M. This course is offered in Spanish and English. Systems Programming is the second course on programming that students take. Both Systems Programming and the previous basic programming course use Java as the programming language, with the basic programming course focusing on Java syntax, simple algorithms, and imperative programming. Therefore, students are supposed to come to Systems Programming with some background on Java. Systems Programming syllabus includes six topics preceded by a recap of imperative programming: (1) object-oriented programming; (2) testing; (3) recursion; (4) linear data structures; (5) non-linear data structures; (6) searching and sorting algorithms. The course is structured in 14 weeks over the semester (29 sessions). Every week there is a large group session with up to 120 students in a traditional classroom, and a small group session with up to 40 students in a computer lab. Large group sessions are typically used for lecturing, while small group sessions are used for practicing and coding in the lab.

Systems Programming is a course which historically shows low passing rates. One of the reasons is that it is not mandatory to have passed the first semester basic programming course to enroll in Systems Programming, and there are students who come to this course with a very low level on imperative programming (having strong difficulties to catch up). Another reason is that, even though this is an eminently practical subject, there is little time for practical activities (one session in the lab per week), and it is difficult to allocate more time for practicing as theoretical sessions follow a strict schedule and take place in large classrooms under the supervision of only one teacher.

In 2017, *407 students* enrolled in this course (325 took it in Spanish and 82 took it in English). In total, there were 4 large groups (3 in Spanish as two degrees were combined in one group, and one in English) and 12 small groups (10 in Spanish and 2 in English). Large group classes were taught by 3 teachers, with 12 teachers overall in the teaching staff. Before starting the course, teachers decided to redesign the structure of large group classes with the aim to promote active learning, implementing a flipped classroom strategy through the reuse of several existing MOOCs (also developed by the teaching staff). Lab sessions and assessment system remained as in previous years.

3.1. REUSING MOOCS TO SUPPORT STUDENTS' WORK OUTSIDE THE CLASSROOM

Since 2015, several teachers from the UC3M Telematics Engineering and Computer Science Departments have been working on a project to create a series of three five-week MOOCs on "Introduction to Java Programming" (one MOOC per year) [9]. This series of MOOCs is currently being offered in edX under a program called "Professional Certificate", which aims towards offering career-oriented courses to develop skills demanded by the labor market. To ensure this demand is met, companies with experience in the sector shall endorse the series of MOOCs. These three MOOCs cover the whole syllabus of the first-semester basic programming course, and of Systems Programming, beyond other cross-cutting topics.

The first MOOC focuses on imperative programming (e.g., variables, methods, loops, conditions, etc.) and object-oriented programming (e.g., object, classes, inheritance, polymorphism, interfaces, etc.); it was developed in 2015 and has been run four times so far (one time as an instructor-led MOOC and three times as a self-paced MOOC). The second MOOC focuses on writing "good" programs, and includes error detection and correction, debugging, testing, complexity, software engineering and ethical issues; it has been run three times so far (one time as an instructor-led MOOC and twice as a self-paced MOOC). The third MOOC focuses on linear and non-linear data structures (e.g., linked lists, stacks, queues, trees, binary search trees, heaps, etc.), as well as on algorithms applied on them (e.g., insertion, extraction, searching, sorting, etc.); it has been run twice so far (one time as an instructor-led MOOC and another time as a self-paced MOOC). The three MOOCs were initially developed in English, and they are being offered in Spanish for the first time in the first half of 2018, as part of an equivalent "Professional Certificate" in Spanish.

In the MOOCs, each week contains: (1) four learning sequences with the main content, (2) a "laboratory" activity with a small programming project, (3) an exam, and, sometimes, (4) additional activities for those who want to practice more. Each of the four main learning sequences combines intertwined videos and formative activities, plus other educational resources. Although videos are an important part in these MOOCs, numerous interactive activities have been developed with edX tools, and other external tools (e.g., Blockly or Codeboard), as well as animations and simulations [10]. The materials of these MOOCs have been improved in their different editions, considering students' comments in the forums and the analytical data provided by edX. As of early 2018, more than *350,000 learners* have enrolled in these three MOOCs on "Introduction to Java Programming" in their different editions.

The contents of the three MOOCs on "Introduction to Java Programming" served to create two "closed" online courses on a local instance of the Open edX platform (hosted at UC3M), for students taking Systems Programming in English and Spanish. These two "closed" online courses contained the materials students had to work with before going to the classroom. In the case of the English edition of Systems Programming, it was possible to cover 100% of its syllabus using contents extracted directly from the three MOOCs in English. These contents were filtered and organized in Open edX to follow the weekly structure of Systems Programming. In the case of the Spanish edition of Systems Programming, as the equivalent MOOCs in Spanish language were not yet ready by the time of running this experience, a hybrid approach was followed for the creation of the equivalent "closed" online course in Open edX. First, two thirds of the course were created practically from scratch directly in Spanish (topics 1, 3, 4, and 5) by the teachers of Systems Programming, including videos, formative activities, and additional resources. The remaining third of the course was built using the materials from the English version of the MOOCs (topics 2 and 6), providing subtitles in Spanish for all the videos. The two "closed" online courses were therefore equivalent at the time of running the experience and were equally valid for the purpose of implementing a flipped classroom strategy. The following school year, after releasing and testing the MOOCs in Spanish in Open edX, the same exact content will be offered to students taking Systems Programming in both English and Spanish.

It is worth noting that only students registered in System Programming had access to these "closed" online courses, and that in these courses all the activities were formative (they were not considered to calculate the final grade of Systems Programming), although these activities could help as preparation for the exams. Finally, those students who came to Systems Programming without having passed the first semester basic programming course were advised to take the first three weeks of the first MOOC offered through edX to catch up.

3.2. FOSTERING MOTIVATION OUTSIDE THE CLASSROOM

UC3M has developed a gamified mobile application for Android and iOS, called Flip-App [11], specifically designed to support courses which implement flipped classroom strategies. Flip-App aims to encourage students to do the previous work before going to the classroom, with a particular focus on watching the required videos and completing the related formative activities. Flip-App is seamlessly integrated with Open edX, and students can see, directly within the mobile application, the overall structure and the weekly content of courses deployed in the Open edX instance hosted at UC3M. The main features of Flip-App are: (1) students can see the percentage they watched for each video (no matter if they watched the video from the mobile application, directly in Open edX from the web browser, or combining both options); (2) students can see with a three-color code the individual contents they completed (green), started (yellow), or nor started (red), including videos and activities; (3) students receive "virtual points" for watching videos and doing activities, as well as for being the first ones accessing/completing certain contents; (4) students can donate points to their classmates; (5) students can see a leaderboard with the points obtained by their classmates during the week, and also where they are located in the leaderboard; (6) teachers can configure notifications and reminders which students receive in their mobile devices. The main limitation of the Flip-App, however, is that interactive activities cannot be done in the mobile application (students need to do them in Open edX from the web browser), although points are awarded anyway if completing activities.

On the learner side, Flip-App is intended to promote the development of self-regulated learning skills through: the establishment of realistic weekly objectives to be achieved; and the increase of motivation and awareness on the work done/pending, with respect to the classmates. On the teacher side, Flip-App is also intended to increase awareness on the work done by learners, as it is integrated with a web-based learning analytics dashboard, which shows visualizations of the videos watched and the exercises done (individually and by the overall class), as well as which videos are the most popular ones, or with which videos learners are struggling (repeating them partially or totally several times). In the school year 2016/2017 Flip-App has been tested in a pilot phase with about 2,000 students from different UC3M courses (including Systems Programming).

3.3. FOSTERING MOTIVATION INSIDE THE CLASSROOM

Large group sessions on Systems Programming were redesigned to promote active learning (small group sessions were already promoting active learning through the development of small projects in pairs in the lab). New large group sessions include three parts: (1) the teacher reviews the main concepts that students should have worked on at home with time for questions; (2) students develop collaboratively simple programs related to these concepts; and (3) the whole class participates in an interactive questionnaire which combines theory and practice using Kahoot! [12]. The first and second parts are usually intertwined; a small program is developed after reviewing a key concept, then continuing with the revision of another concept; the third part is usually done at the end of the class.

The *first part* is guided by the teacher and has a twofold purpose: students who watched the videos and did the activities some days ago recall the concepts; and students who did not complete the homework get, at least, a general idea of the key concepts. The time devoted to this part requires an appropriate balance and is about 20-30 minutes. In the *second part*, students work with classmates sitting next to them in a small project (the classroom is not very flexible with chairs and tables attached to the floor). The teacher goes through the different groups solving errors on their code, so that students can advance faster. At the end, the teacher shows a reference solution of the program. Time devoted to this part is about 40-45 minutes. In the *third part*, the whole class takes a questionnaire of about 20-25 questions that the teacher has prepared with theoretical and applied questions. The questions are displayed on the screen one by one, some of them including code snippets, and there are always four possible answers. Students can select an answer directly from their mobile devices or laptops. Each question lasts between 20 to 60 seconds depending on its difficulty. The whole class moves forward at the same pace. After each question, the teacher sees a bar chart with students' answers and can decide whether to provide an additional explanation or to move to the following question. After each question, students see the points obtained (if answering correctly and fast) and where they stand on the leaderboard with respect to their peers. Time devoted to this part is about 30-40 minutes.

4. Results and Discussion

Two data sources were used to collect and analyze data related to this experience. First, a voluntary, anonymous questionnaire was sent to the students after the first five weeks of the course, and before the first mid-term exam (to avoid biases in students' opinions due to the grade obtained in the mid-term exam). This questionnaire aimed to collect data on the usefulness of the several innovative elements used in the implementation of the flipped classroom strategy, and on the effect these innovative elements had on students' motivation. The questionnaire contained a set of statements to be assessed by the students on a Likert-5 scale (from strongly agree to strongly disagree), related to the usefulness and increase of motivation of the innovate elements introduced both outside the classroom (videos and formative activities) and inside the classroom (interactive questionnaires and small collaborative coding projects). Additional space was left also for open comments to triangulate them with the findings from the Likert-5 scale questionnaire. A total of 102 students (25% of enrollees) completed the questionnaire (30 of those taking the course in English, and 72 of those taking the course in Spanish). This is an important limitation of the study, causing some bias, as typically voluntary questionnaires are answered by those students who have either very positive or very negative experiences with the innovation that is implemented.

Secondly, data obtained from Kahoot! was used to compare the differences between groups, both in terms of participation and learning. After analyzing the available data and determining which sessions and groups could be compared (because class time conformed to the structure presented in the previous section), data from the first four sessions of three out of the four large groups were used: English group (GING), and Spanish groups of Audiovisual Systems Engineering (GISA) and Telecommunications Technologies Engineering (GITT).

4.1. Students' Work outside the Classroom

The first step is to find out if students used the content offered through Open edX as expected in a flipped classroom. 61.8% of the students, indicated that they used this content to prepare the coming classes. Nevertheless, 34.3% of the students indicated that they used this content only to review concepts they did not understand in class. Finally, 3.9% of the students indicated that they did not use the content offered through Open edX at all. This result reveals the differences between students' behavior, with an important gap in a freshman course such as this one. On the one hand, there were students who reacted better to the implementation of the flipped classroom strategy, becoming responsible for their own learning, and devoting time at home to make better use of class time. On the other hand, there were students who continued with the mentality that the time spent on a course is primarily attending to class, thus not benefitting from the implementation of the flipped classroom strategy. This reluctance of some undergraduate students to the flipped classroom is consistent with the findings of other studies [41][42].

Students who used the content offered through Open edX were asked about the *usefulness* of such content for their learning, and about whether this content increased their *motivation* to work on the course (see Figure 1). As for the usefulness of the content, 90.9% of the students agreed or strongly agreed on the usefulness of the videos for their learning, while 84.7% agreed or strongly agreed on the usefulness of the formative activities intertwined with the videos for their learning. These results were complemented by several positive related comments: "It [the content] is very well organized in order to have previous knowledge of what will be taught in the classes," "It [the content] helps a lot, and the [formative] exercises help to deal with special cases that with the theory may not be completely clear," "if I am not clear on some concept, I can repeat the video over and over again until I get it." These findings are consistent with other works which analyzed the role of videos in the implementation of flipped classrooms strategies, such as in [43], where students also highlighted the usefulness of videos, as these can be paused/played/rewound as necessary. Some critical comments referred to the length of videos (which in some cases could be shorter) or to the feedback provided in formative activities: "Although most of the videos are from 3 to 5 minutes, some of them last almost more than 10 minutes and consequently are a bit tedious to follow," "I would add more feedback on exercises."

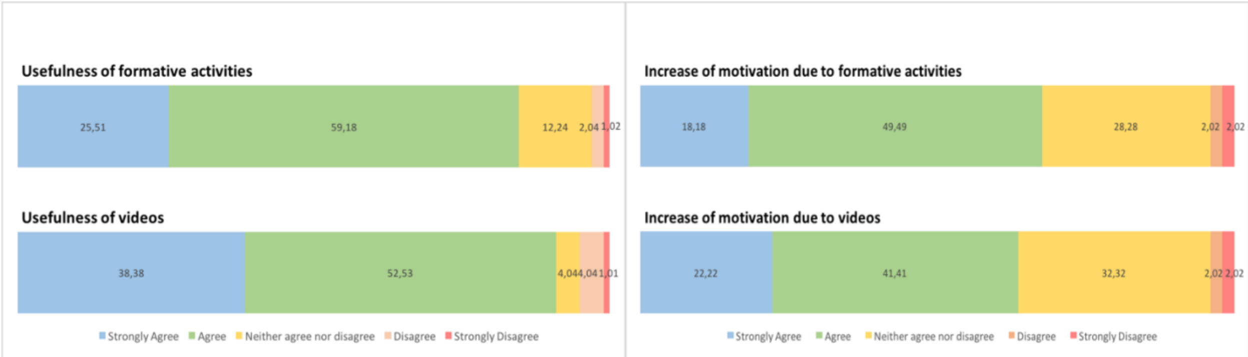

Figure 1: Usefulness for students' learning of videos and formative activities (left) and increase of students' motivation due to the videos and formative activities (right)

As for the increase of motivation due to the content provided, 63.6% of the students agreed or strongly agreed on the fact that the videos increased their motivation, while 67.7% agreed or strongly agreed on the fact that the formative activities intertwined with the videos increased their motivation. It is interesting to note that despite the high percentage of students assessing positively the usefulness of videos and formative activities, the effect of these on students' motivation to work on the course was not so high. The part of the flipped classroom carried out outside the classroom typically has an individualistic nature, which can be less motivating compared to the part carried out inside the classroom, where there is more interaction with teachers and classmates. These results on the effect of videos and formative activities on motivation were complemented by several positive comments: "I am repeating this course and thanks to this type of teaching I am having the motivation that I didn't get last year," "I am very satisfied and motivated thanks to this format; I would like all courses to be taught in this way." Critical comments mainly referred to the use of the contents as part of the assessment system of the course: "maybe doing all the [formative] exercises should be considered in the grade."

Regarding the use of Flip-App, only 38.2% of students indicated that they were using it. Positive comments on the use of Flip-App mainly referred to its purpose and functionality: "It is a good motivation for students to improve themselves and beat their colleagues," "It forces me to constantly work on the course," "I think it is a very good idea and the competition between classmates is useful and fun," "I like that it reminds you to watch the videos". Negative comments mainly referred to installation problems, as the application was developed to be compatible with both Android and iOS devices, but it was not offered through the official app markets (e.g., "[Apple] devices detect this app as a threat, or that it is "illegal" by not being inside Apple Store,"). Students also mentioned additional features which could be added to Flip-App (e.g., "It could include exercises as well"). Surprisingly, although Flip-App was introduced the first day of class, and its usage information and download links were available in the official website of Systems Programming, several students reported that they did not know it. These results show that despite the positive perception of those students who used Flip-App regarding its usefulness and increase in motivation, it is necessary to have technical staff available for solving technical problems that may discourage students from using the application, as well as to periodically remind the advantages that an application such as this one can have when working on a course which implements a flipped classroom strategy.

4.2. STUDENTS' WORK INSIDE THE CLASSROOM

To evaluate the redesign of large group classes as part of the implementation of the flipped classroom strategy, students were asked about the *usefulness* and increase in their *motivation* of the two main novelties: the collaborative development of simple programs intertwined with the review of the key concepts, and the realization of interactive questionnaires with Kahoot! (see Figure 2). As for the usefulness of the two main novelties used inside the classroom: 90.2% of the students agreed or strongly agreed on the usefulness for their learning of developing simple programs in collaboration during the class, while 87.2% of the students agreed or strongly agreed on the usefulness for their learning of doing interactive questionnaires with Kahoot! These results were complemented by several positive related comments: "[The programs developed] help me connect concepts, remember them and often learn from mistakes," "As we have been working with the same [Java] class, and new contents were given and applied to it, everything is much more structured," "[Kahoot! helps] to revise [the concepts] quite well." Critical comments mainly referred to some constraints related to the infrastructure of the classroom, the available time, as well as the bad behavior of some classmates: "The problem is that there are not enough power sockets in the classroom, so it is hard for everyone to use their personal computer [to develop the small programs]," "There is no time to solve them [the small programs], and in the end, everything is done very fast," "[In the Kahoot!], a lot of time is wasted between questions; the problem is that some students behave like teenagers and often the teacher is not even listened to." These comments highlight several problems related to class orchestration when it comes to a first-year undergraduate course, where there are many students in class and some of them lack the level of maturity expected at the university. It is part of the teacher's role to try to adjust the time in each session to the activities to be done, to try to manage the noisy environment that can occur when doing interactive and collaborative activities, and to try to find classrooms that may have enough sockets for students to work with their laptops.

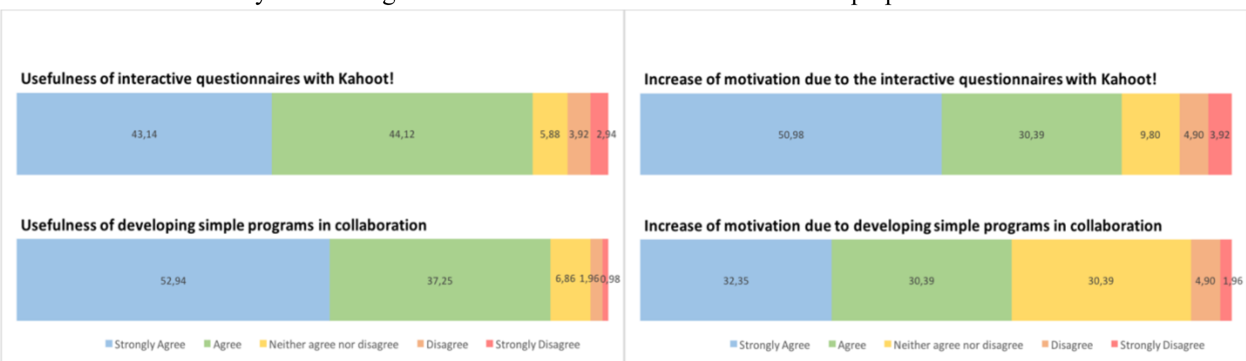

Figure 2: Usefulness for students' learning of developing simple programs in collaboration and doing interactive questionnaires with Kahoot! (left) and increase of students' motivation due to the development of simple programs and realization of interactive questionnaires with Kahoot! (right)

As for the motivation, 62.8% of the students agreed or strongly agreed that the development of simple programs in collaboration inside the classroom increased their motivation, while 81.4% of the students agreed or strongly agreed that the realization of interactive questionnaires with Kahoot! increased their motivation. It is noteworthy that the use of Kahoot! has been the innovation that most contributed to increase students' motivation in the implementation of this flipped classroom strategy. This fact is also supported by students' comments: "They [Kahoot! questionnaires] motivate me a lot, and I have a great time! I wish there was more of this in the other courses!!" "I have never worked with it [Kahoot!] before, and it was a big surprise. It makes the classes so much fun," "I find it [interactive questionnaires with Kahoot!] an activity that makes classes much more enjoyable; something different that gives a breath of fresh air to the usual university atmosphere (boring and monotonous)," "Everyone wants Kahoot! time to come, which, apart from serving to learn, motivates thanks to the competition between colleagues." Students were also asked if competing with their classmates in Kahoot! questionnaires increased their motivation, and 79.4% agreed or strongly agreed (with 61.8% in strong agreement). These results are consistent with other studies of the use of Kahoot! in the classroom, which usually presents improvements in students' motivation [44][45]. Nevertheless, there were also a couple of critical comments with Kahoot!, mainly related to using the time for Kahoot! questionnaires to develop more programs instead: "Using Kahoot! seems to me like wasting an hour of class when we could be doing more practical exercises." In this case, it is also the teacher's role to balance the class time dedicated to each type of activity, while introducing different dynamics that allow students to apply theory and practice and be aware of their limitations regarding the concepts of the course.

Tools like Kahoot! increase awareness for students and teachers. On the one hand, students increase their awareness on the concepts they do not grasp and compare themselves with the rest of the class to see if their level for a certain topic is appropriate. On the other hand, teachers increase their awareness getting information, in real-time, on the overall class knowledge for a certain topic. In particular, teachers can detect which concepts are unclear and compare different groups through the same Kahoot! questionnaire. Figure 3 shows a comparison of the percentages of total correct answers and participation for three different groups (GITT, GISA and GING), the first two taking the Systems Programming in Spanish, and the third one in English. First of all, the teacher can detect that GITT and GING generally perform better than GISA, so this latter group needs more explanations during the realization of the Kahoot!, and also complementary exercises as homework. Moreover, the teacher can monitor attendance levels in large group classes (usually almost all students who attend class participate in Kahoot!). Participation percentages (as attendance levels) tend to decrease as the sessions go by until they stabilize. In this case, attendance levels may be conditioned by the fact that students who are not consistently working in the course will not take advantage of class time. In addition, as they have access to videos and formative activities, they might think that this is enough to prepare the course on their own. Finally, it should be noted that in sessions 1 of GITT and 2 of GISA it was not possible to complete the Kahoot! questionnaire. Although classes were planned with timeframes for each part, students' questions may lead to variations in these timeframes, to the detriment of the last part (the interactive questionnaire with Kahoot!). In any case, teachers shared the links to the Kahoot! questionnaires with the students, so that they could complete them at home, as many times as they wished.

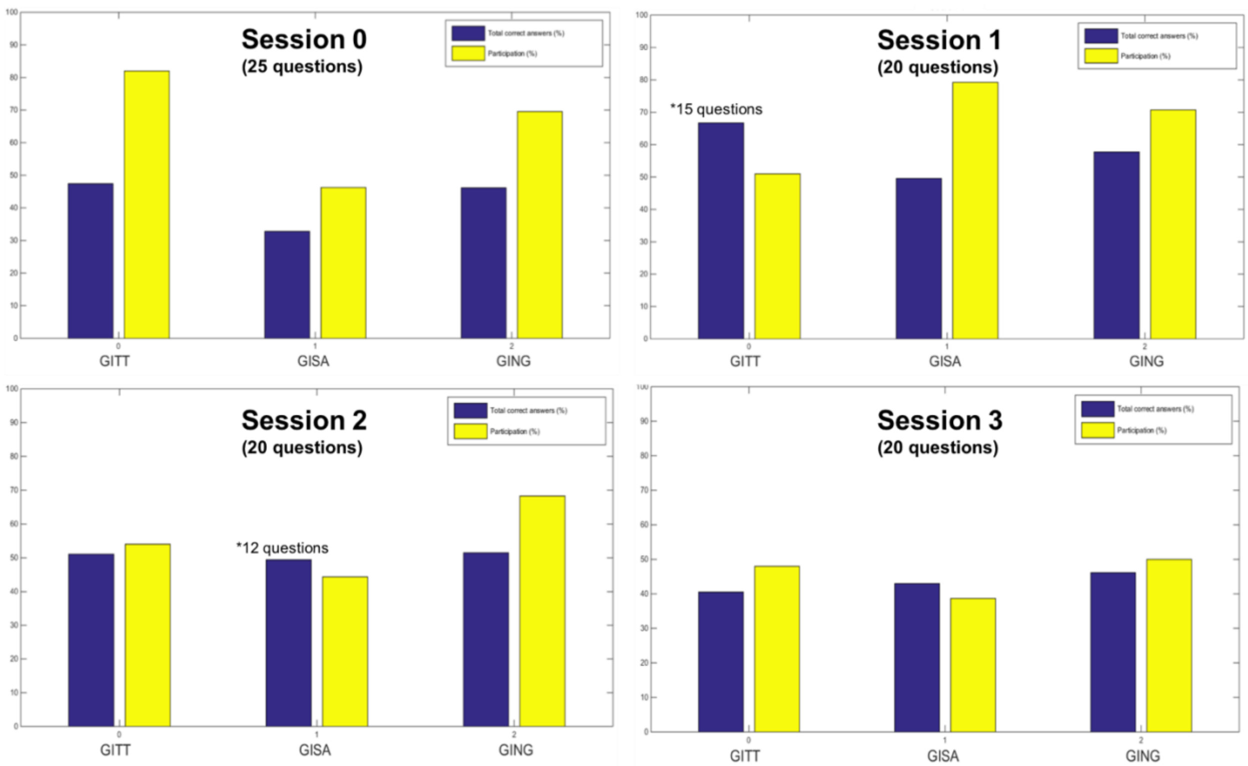

Figure 3: Comparison of the percentage of total correct answers (dark blue) in Kahoot! and percentage of participation (yellow) throughout four consecutive sessions between three large groups: English group (GING), and Spanish groups of Audiovisual Systems Engineering (GISA) and Telecommunications Technologies Engineering (GITT). There was not enough time to complete the full questionnaires in Session 1 of GITT (15 questions out of 20) and in Session 2 of GISA (12 questions out of 20).

5. Conclusions and Future Work

This paper has presented the experience of implementing a flipped classroom strategy through the reuse of MOOCs, in a first-year undergraduate engineering course, where face-to-face large group sessions were redesigned to include hands-on, interactive activities. With regards to the first research question on how to redesign freshman courses to implement flipped classroom strategies, teachers must plan carefully all the weekly activities that students must complete in advance outside the classroom, and then the subsequent activities that must be done inside the classroom. The characteristics of the new generation of students shall be considered providing quality content in the form of short videos intertwined with formative exercises for the work outside the classroom, and intertwining explanations and practical and interactive activities for the activities inside the classroom, stimulating students with changes of pace, for example, fostering collaborative learning or increasing students' motivation through competition. With regards to the second research question on how to change students' minds towards the flipped classroom by increasing their motivation, different innovations were tested: short video lectures, online formative activities, face-to-face collaborative problems, and face-to-face interactive questionnaires. Although all of them have shown to increase students' motivation, the interactive questionnaires with Kahoot! obtained better results. Contrary to what was expected, Flip-App had moderate success in increasing students' motivation outside the classroom.

The conclusions obtained in this paper have several limitations, which must be addressed as future lines of work. First, only about a quarter of the total number of enrolled students answered the voluntary, anonymous questionnaire. While not all enrollees follow Systems Programming from the beginning (especially if they did not pass the first-semester basic programming course), it is important to be aware that results on students' perceptions of the innovations introduced as part of this experience may be biased, since students with more positive or more negative perceptions are usually those who answer voluntary self-reported questionnaires. Second, the data sources used to evaluate the experience were limited, and it would be interesting to triangulate the results shown here with students' performance in terms of learning gains. To this end, a control group and an experimental group could have been used, although for ethical reasons teachers decided to implement the same flipped classroom strategy in all groups and collect information from anonymous questionnaires (including Kahoot! questionnaires). Third, this experience refers to an engineering course of a special type on software development. Equivalent experiences should be conducted in other freshman engineering courses to evaluate the replicability of the design proposed here. Fourth, a flipped classroom strategy has been implemented here with the help of the Open edX platform to provide the context and structure of the learning sequences (mainly sets of intertwined videos and formative activities) students had to work with at home. The effect of the platform could be isolated, providing the materials to be worked at home in different forms. For example, videos could be provided directly as a playlist in YouTube, while formative activities could be provided in textual documents. The hypothesis would be that the structuring of the tasks to be done at home under the same environment (the Open edX platform) contributes in the positive perception of their usefulness and increase of motivation by the student. Finally, it is noteworthy that Flip-App was integrated in Open edX, as this is the platform used at UC3M to deploy contents taken from MOOCs for on-campus students. It would be interesting to see how Flip-App can be integrated in other e-learning platforms, such as Moodle, and to analyze the replicability of this study in such platforms.

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BIOGRAPHIES

Carlos Alario-Hoyos is a Visiting Associate professor at Universidad Carlos III de Madrid. He received M.S. degree in Telecommunication Engineering and PhD in Information and Communication Technologies from Universidad de Valladolid, Spain, in 2007 and 2012 respectively. He is author or co-author of more than 75 scientific publications and has participated in more than 20 research projects, at regional, national and European levels. His skills and experience include research and development in MOOCs, social networks, collaborative learning, and evaluation of learning experiences, among others.

Iria Estévez-Ayres is an Associate Professor at the Telematic Engineering Department at Universidad Carlos III de Madrid. She obtained her Telecommunication Engineering degree from Universidad de Vigo in 2001 and her PhD from Universidad Carlos III de Madrid in 2007. She has been involved in several international and national projects and is author or co-author of more than 60 scientific publications in the fields of technology-enhanced learning, networking, distributed systems and real-time systems.

Carlos Delgado Kloos received the PhD degree in Computer Science from the Technische Universitat Munchen and in Telecommunications Engineering from the Universidad Politécnica de Madrid. He is full professor of Telematics Engineering at the Universidad Carlos III de Madrid, where he is the director of the GAST research group, director of the UNESCO Chair on "Scalable Digital Education for All", and Vice President for Strategy and Digital Education. He is also the Coordinator of the eMadrid research network on Educational Technology in the Region of Madrid. He is the Spanish representative at IFIP TC3 on Education.

Pedro J. Muñoz-Merino is Associate Professor at Universidad Carlos III de Madrid, where he is the Director of the Master in Telematics Engineering. His skills and experience include research and development in learning analytics, educational data mining, evaluation of learning experiences, user studies, gamification or Intelligent Tutoring Systems. Pedro is the coordinator of the LALA project, funded by the European Union for the adoption of learning analytics in Latin America. Pedro has participated in more than 40 research projects at the international and national level, including also several contracts with companies, being the Principal Investigator of several of them related with learning analytics, educational data mining and adaptive systems. Pedro has received several awards for his work on educational technologies. He is author of more than 100 scientific publications. He has also coordinated the development and deployment of different learning analytics tools. At present he is coordinator of the work group about learning analytics and adaptive systems in IEEE Spain chapter about education.

Enrique Llorente-Pérez is a graduate student in Telecommunications Engineering in Universidad Carlos III de Madrid. He has supported several research initiatives about education, specifically in areas related to MOOCs and SPOCs (Small Private Online Courses), and the analysis of students' interaction with them. Moreover, Enrique's research includes flipped classrooms strategies and different educational tools used to support these strategies, such as Kahoot!. His skills and interests include data analysis, machine learning and programming tools.

Julio Villena-Román received his degree in Telecommunications Engineering from Universidad Politécnica de Madrid in 1997, where he began his professional career with a 3-year research fellowship. In 1998 he was one of the founding members of Daedalus, a private company working the field of Language Technologies. He is currently Director of Innovation at the private company MeaningCloud LLC. He is also a part-time lecturer in the Telematics Engineering Department at University Carlos III de Madrid since 2002.